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SPECKLE INTERFEROMETRY AT MOUNT WILSON OBSERVATORY: OBSERVATIONS OBTAINED IN 2006–2007 AND 35 NEW ORBITS

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ABSTRACT

Results are presented for 607 speckle interferometric observations of double stars, as well as 222 measures of single stars or unresolved pairs. All data were obtained in 2006 and 2007 at the Mount Wilson Observatory, using the 2.5 m Hooker telescope. Separations range from 0″.06 to 6″.31, with a median of 0″.34. These three observing runs concentrated on binaries in need of confirmation (mainly *Hipparcos* and *Tycho* pairs), as well as systems in need of improved orbital elements. New orbital solutions have been determined for 35 systems as a result.

Key words: binaries: general – binaries: visual – techniques: interferometric

Online-only material: color figures, machine-readable and VO tables

1. INTRODUCTION

Mount Wilson Observatory has been at the center of interferometric research for nearly all of its history, from the 20 foot beam used on the Hooker 100 inch telescope to measure the separations of close binary stars (Anderson 1920; Merrill 1921) and the first stellar diameter (Michelson & Pease 1921), to the Pease 50 foot interferometer, to multi-aperture instruments such as the Mark III (Shao et al. 1988), the Infrared Spatial Interferometer (Bloemhof et al. 1986), and the CHARA Array (McAlister et al. 2005). Also, the CHARA speckle camera was used at the 100 inch telescope shortly before that telescope's closure in 1985, then in a five-year series of observations following the telescope's reopening in 1993 (cf., Hartkopf et al. 1997).

The USNO speckle camera finally visited that hallowed ground for a run on the 100 inch in 2006 July, followed by runs in 2007 April and October. Results of those observing efforts, as well as new orbital elements derived in part from these new data, are presented below.

2. EQUIPMENT AND CALIBRATION

During equipment setup for our 2006 run, it was discovered that the ICCD for the USNO speckle camera had suffered a mechanical failure. Fortunately, the CHARA speckle camera (cf., Hartkopf et al. 2000) was in storage on the mountain, and despite eight years since its last use, this vintage-1991 ITT RS-170 detector (Mason et al. 1993b) worked immediately. After fabrication of a new cable, we were able to use this camera for the duration of the run; despite some time lost to clouds, 525 observations were obtained over six nights.

The speckle camera used for the two 2007 runs was described most recently in Mason et al. (2009). Data were obtained on 3.5 of six nights in April (446 observations) and on four of nine nights in October (569 observations). Time was lost in April due to high winds and snow, as well as ash from a major fire outbreak. Much of the October run was also lost due to Santa Anna winds and to ash from another major fire.

Absolute calibration of data for each run was obtained through the use of a slit mask mounted at the end of the telescope (see Figure 1). By observing a bright single star using this mask, an "artificial" double star is created, whose separation and position angle are defined by the slit spacing and orientation. Details of the slit mask and calibration technique are given in Hartkopf et al. (1997).

3. RESULTS

A total of 607 new measures are given in Table 1, where Columns 1 and 2 give the Washington Double Star (WDS[1]) and discoverer designations and Columns 3–5 list the epoch of observation (as fractional Besselian year), derived position angle (in degrees), and separation (in arcseconds). Poorer quality measures are indicated by a colon following θ and ρ. Column 6 lists the filter (Strömgren *y*, USNO *g*, or Johnson *V*) used in the observation; effective wavelength and FWHM values for these filters are listed at the end of the table.

For systems with published orbital elements in the *Sixth Catalog of Visual Orbits* (ORB6[2]), residuals in θ and ρ to that orbit are given in Columns 7 and 8, respectively. Column 9 gives a code for the orbit reference, based on the author's last name and the date of publication; all reference codes are included in the list of references below. Occasionally, ORB6 lists more than one "preferred" orbit, in which case residuals to both orbits are included. Also included in these columns are residuals to 35 new orbits, as described below and listed in Table 3. Coarse orbit grades (either as listed in ORB6 or calculated for the new solutions) are given in Column 10; these grades, on a scale of 1 ("definitive") to 5 ("indeterminate"), are described by Hartkopf et al. (2001) and are based on similar grading schemes used in earlier orbit catalogs.

The final column flags notes to the observations. A "C" indicates that this is a confirming observation to a pair with only a single published measure in the WDS database. A "d" indicates that the new measure is quite different in θ ($> 30^\circ$) and/or ρ ($> 30\%$) from either the most recent published measure or the values predicted by the indicated published orbit. In many cases, these discrepancies are the result of orbital motion during the interval since the last observation; in other instances they indicate the need for an update of the orbital elements.

The 222 observations of 220 single stars and unresolved pairs are listed in Table 2. Here, Columns 1, 3, and 4 are the same as in Table 2. Column 2 lists either the discoverer designation

[1] http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/WDS
[2] http://www.usno.navy.mil/USNO/astrometry/optical-IR-prod/wds/orb6

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Table 1
Speckle Interferometric Measurements

WDS Desig. α, δ (2000)	Discoverer Designation	Epoch 2000.+	θ (°)	ρ ($''$)	Filt	$O-C$ (θ)	$O-C$ (ρ)	Orbit Reference	Orbit Grade	Note
00002+4119	TDS 1235	2007.8013	54.6 :	1.208 :	V					C,d
00021+5556	TDS 1258	2007.7987	246.0	0.725	V					C
00121+5337	BU 1026 AB	2007.7987	310.0	0.323	y	−0.7	−0.009	Har1996	2	
00134+2659	STT 2 AB	2007.8179	162.5	0.401	y	0.9	0.010	Har2008	3	
00308+4732	BU 394	2007.8013	275.3	0.544	y	0.4	−0.027	Zul1997	4	
00318+5431	STT 12	2007.7987	205.1	0.287	y	−2.4	0.084	Lin2005	4	d
00335+4006	HO 3	2007.8013	167.4	0.230	y	8.7	−0.010	Cve2006	3	
00339+5316	TDS 1523	2007.7987	90.3	0.662	V					C,d
00441+5655	TDS 1589	2007.7987	317.3	0.769	V					C
00456+5457	TDS 1602	2007.7987	68.8	0.436	V					C

Notes. C: Confirming observation (only one published measure in WDS).
d: Large difference in θ (> 30°) and/or ρ (> 30%) compared with last published observation or orbit ephemeris.
q: Quadrant was flipped by 180° for the new orbit relative to the published one.
Filters: Strömgren y ($\lambda_{\rm eff}$ = 550 nm, FWHM = 24 nm), USNO g (560/45 nm), Johnson V (545/ 85 nm).
Orbit grades: 1, "definitive;" 2, "good;" 3, "reliable;" 4, "preliminary;" 5, "indeterminate." See *Sixth Orbit Catalog* for more details on orbit grading.
(This table is available in its entirety in machine-readable and Virtual Observatory (VO) forms in the online journal. A portion is shown here for guidance regarding its form and content.).

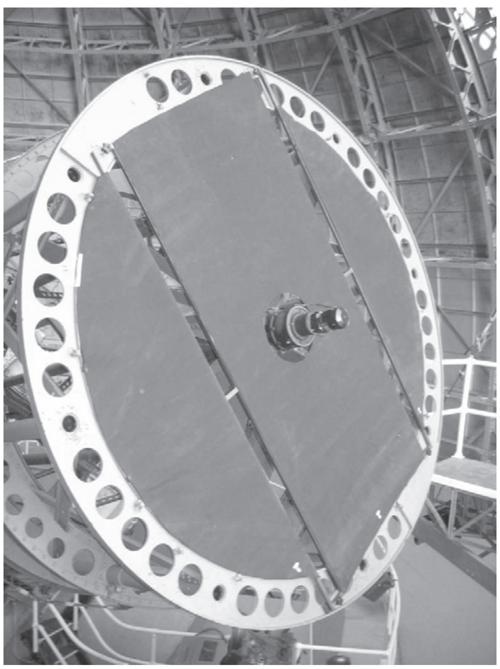

Figure 1. Slit mask mounted on the Hooker telescope. The slits themselves are rigid 3 m by 10 cm frames, constructed of square aluminum tubing; black canvas covers the remainder of the telescope opening. Slits are separated by 1.330 m, with exact positioning defined by multiple registration pins.

(as in Table 1) for a binary star, or the *Hipparcos* number for an object never resolved into a double. Column 5 gives rather more extensive notes to the object, as described at the end of the table. The most common note code is "U," indicating a pair whose discovery observation (the date and separation of which are listed in parentheses) remains unconfirmed. References to the observation or orbit mentioned in the notes column are listed in Column 6.

4. NEW ORBITAL SOLUTIONS

New orbital solutions were attempted for all systems in Table 1 where recent measures showed considerable residuals from published elements. The "grid search" method used for these calculations is described by Hartkopf et al. (1989), with the weighting system for individual observations described by Hartkopf et al. (2001). A total of 35 systems yielded new solutions which were deemed sufficiently improved for publication. Elements for these systems are given in Table 3, where Columns 1 and 2 give the WDS and discoverer designations and Columns 3–9 list the seven Campbell elements: P (period, in years), a (semimajor axis, in arcseconds), i (inclination, in degrees), Ω (longitude of node, equinox 2000, in degrees), T_0 (epoch of periastron passage, in fractional Besselian year), e (eccentricity), and ω (longitude of periastron, in degrees). Rough grades for each new orbital solution are given in Table 1, as for all other referenced orbits.

Figures 2–7 show the new orbital solutions, plotted with all published data in the WDS database. In each of these figures, micrometric observations are indicated by plus signs, interferometric measures by filled circles or (for the new USNO measures) filled stars, *Hipparcos* and *Tycho* measures by the letters "H" or "T." "$O-C$" lines connect each measure to its predicted position along the new orbit (shown as a thick solid line). A dot-dashed line indicates the line of nodes, and a curved arrow in the lower right corner of each figure indicates the direction of orbital motion. Finally, the previous published orbit is shown as a dashed ellipse; references to each of the published orbits are given in Column 9 of Table 1.

A note about orbit grading is perhaps in order. Of the 35 pairs with new orbital solutions, one saw an improvement by two numeric grades and 14 by one grade. Another 18 were unchanged (at least to the nearest integer grade) and the remaining two saw their grade fall from 4 to 5. These last two systems perhaps illustrate the limitations of reducing a quasi-subjective determination of orbit quality to a numeric formula. The grade is based on a number of factors, including number of observations, mean orbit residuals, phase coverage, etc. (see the ORB6 webpage for a more complete discussion of the procedure used). For these two pairs (09591+5316 and 21047+0332), a glance at the figures shows that the new orbits obviously provide a better fit to the data than the solutions published two decades ago. However, these new solutions are of considerably longer period than the earlier fits, thus decreasing the phase coverage by these data and consequently lowering the calculated orbit grades. Although on

Table 2
Unresolved Objects

WDS α, δ (2000)	Disc. Designation or HIP	Epoch	Filt	Note	Reference
00124+4558	HDS 27	2007.8013	y	U (1991, 0.″12)	HIP1997a
00240+4912	HDS 55	2007.8013	y	U (1991, 0.″17)	HIP1997a
00292+4043	TDS 1488	2007.8013	V	U (1991, 0.″47)	Fab2002
00394+2115	HIP 3093	2007.8179	y	W (54 Psc = STT 550A)	
00542+4318	COU 1654	2007.8014	g	C (orbit: 0.″042)	Sey2002
00586+4153	TDS 1697 AB	2007.8014	V	U (1991, 0.″42)	Fab2002
01014+4900	TDS 1721	2007.8013	V	U (1991, 0.″47)	Fab2002
01016+3318	TDS 1727	2007.8179	y	U (1991, 0.″37)	Fab2002
01021+3658	TDS 1731	2007.8179	V	U (1991, 0.″58)	Fab2002
01072+4933	HDS 145	2007.8013	y	U (1991, 0.″13)	HIP1997a

(This table is available in its entirety in machine-readable and Virtual Observatory (VO) forms in the online journal. A portion is shown here for guidance regarding its form and content.)

the whole, the numerical grading formula reproduces the subjective grades of earlier orbit catalogs reasonably well (and can perhaps track incremental improvements in orbit quality fairly accurately), the eye and brain are still superior in judging more substantial changes in orbital fits.

Table 4 gives ephemerides for each new orbit over the years 2010 through 2020, in two-year increments. Columns 1 and 2 are the same identifiers as in the previous table, while Columns (3+4), (5+6),... (13+14) give predicted values of θ and ρ, respectively, for the years 2010.0, 2012.0, etc., through 2020.0.

5. NOTES TO INDIVIDUAL ORBIT SYSTEMS

01014+3535 = COU 854. The mass sum predicted from these elements is about 3.4 ± 2.4 $M_{\odot}$; the value is about 40% too high for this pair of F8 dwarfs, but the large formal errors make this difference of little consequence.

01443+5732 = BU 870 AB. A nearby companion (separation 13″) was discovered in 1916 (Guillaume 1931) but never confirmed; perhaps it is lost in the glare of the bright primary. A 10th magnitude star 2.7 arcminutes from BU 870 was discovered by Arnold (2004) to share common proper motion; relative astrometry subsequently gleaned from *Tycho* and the Two Micron All Sky Survey (2MASS), as well as archival astrographic plates dating as far back as 1910, confirms that the stars' relative position remains unchanged.

01570+3101 = A 819 AB. A 10th magnitude companion at 66″ shares common proper motion with this close pair, and is probably physical.

02517+4559 = A 1281. A high proper motion system; the primary is of spectral type G5V, and based on the magnitude difference the secondary is probably an early-K dwarf.

02586+2408 = BU 1173 AB. The 13th magnitude C component at 4.″6 is probably physical.

03423+3141 = COU 691. The pair consists of two equal-magnitude F8 dwarfs. Due to their fairly eccentric, inclined orbit, the stars reached a minimum separation of about 14 mas in early 2004, which would have required a 10 m class telescope for resolution.

03463+2411 = BU 536 AB. The relative motion of these two Pleiades stars can be fitted perhaps equally well by assuming that they are an optical pair in rectilinear motion. Their close proximity argues for physicality, although their location within a cluster somewhat lessens the strength of that argument.

03484+5202 = HU 546. The primary is listed as G6IV in SIMBAD; the small magnitude difference suggests the secondary is also G6IV or slightly later. These elements, coupled with a *Hipparcos* parallax of 19.75 ± 2.97 mas, yield a mass sum of about 1.1 ± 0.5 $M_{\odot}$—about a factor of 2 too small. However, given the large parallax uncertainty, this can be resolved by a decrease in π of only 1.2σ.

04262+3544 = HU 608. A pair of F8 dwarfs; the large formal errors for the elements make any mass estimate meaningless for this system.

06323+5225 = WOR 6. GJ 235 consists of two M0 dwarfs; at an estimated distance of about 20pc (Johnson & Wright 1983), these orbital elements yield a mass sum of about 2.1 solar masses, about a factor of 2 too high. Unfortunately, no *Hipparcos* or other recent parallax data are available.

06532+3826 = COU 1877. NLTT 17106 = 60 Aur consists of an F5V primary and a secondary of spectral type about K0 (based on magnitude difference). The mass sum resulting from this orbit (1.9 $M_{\odot}$) is much more reasonable than might be expected, given the large errors in the elements.

07560+2342 = COU 929. The high proper motion pair NLTT 18641 = G 91-20 was first resolved by lunar occultation in 1970 (de Vegt & Gehlich 1976), then by micrometry a few years later (Couteau 1973). The spectral type of the primary is listed as G0; based on the *Hipparcos* magnitude difference the secondary is about G5. These orbital elements, combined with the *Hipparcos* parallax (15.93 ± 0.90 mas) predict a mass sum of 2.03 ± 0.36 $M_{\odot}$, in quite good agreement.

09591+5316 = A 1346. An F8V primary and ~G2 secondary; the predicted mass sum of 4.7 ± 2.7 $M_{\odot}$ is about a factor of 2 too high.

12268−0536 = A 78. This pair has nearly completed one full revolution since its discovery by Aitken (1900). The primary is an F4V, the secondary approximately F8/G0. The mass sum estimated from this solution is 2.8 ± 1.0 $M_{\odot}$, in reasonable agreement for these types.

14122+4411 = STT 278. Spectral types are F2IV and perhaps either F5IV or a late-A dwarf. The predicted mass sum (1.6 ± 0.7 $M_{\odot}$) looks to be an underestimate.

15031+4439 = CHR 43. This pair was discovered in 1985 at the Canada–France–Hawaii Telescope (CFHT) 3.6 m, during a speckle duplicity survey of stars in the Yale *Bright Star Catalogue* (McAlister et al. 1987b), as were fellow Table 3 entries 15513−0305 = CHR 51 and 22383+4511 = CHR 114.

Table 3
New Orbital Elements

WDS (Figure No.)	Discoverer Designation	P (yr)	a ($''$)	i ($^\circ$)	Ω ($^\circ$)	T_o (yr)	e	ω ($^\circ$)
00520+3154 (2a)	A 924	182.57 ± 16.74	0.296 ± 0.001	154.2 ± 6.2	44.8 ± 18.1	1986.54 ± 0.53	0.704 ± 0.021	318.2 ± 17.6
01014+3535 (2b)	COU 854	68.11 ± 3.71	0.149 ± 0.005	150.4 ± 7.7	221.1 ± 10.4	1999.59 ± 4.24	0.123 ± 0.022	127.0 ± 21.4
01443+5732 (2c)	BU 870 AB	193.17 ± 6.23	0.899 ± 0.012	134.8 ± 3.8	128.8 ± 4.6	2022.39 ± 0.78	0.773 ± 0.016	270.2 ± 7.4
01570+3101 (2d)	A 819 AB	164.18 ± 32.89	0.437 ± 0.025	48.6 ± 4.0	170.6 ± 10.6	2010.04 ± 1.63	0.462 ± 0.076	149.7 ± 31.5
02517+4559 (2e)	A 1281	146.40 ± 5.03	0.491 ± 0.006	42.0 ± 2.8	161.0 ± 4.0	1936.37 ± 1.45	0.328 ± 0.017	148.4 ± 6.4
02586+2408 (2f)	BU 1173 AB	296.96 ± 69.00	0.377 ± 0.001	76.6 ± 1.7	105.5 ± 2.7	2029.02 ± 3.10	0.607 ± 0.058	70.6 ± 9.9
03423+3141 (3a)	COU 691	35.07 ± 1.31	0.184 ± 0.037	76.1 ± 20.8	241.1 ± 7.6	2004.10 ± 3.02	0.685 ± 0.317	75.5 ± 40.7
03463+2411 (3b)	BU 536 AB	885.64 ± 385.32	1.211 ± 0.124	99.3 ± 2.3	175.3 ± 0.7	1877.90 ± 73.36	0.314 ± 0.002	245.5 ± 62.5
03484+5202 (3c)	HU 546	69.37 ± 0.49	0.344 ± 0.005	148.2 ± 2.9	264.3 ± 4.6	1973.87 ± 0.95	0.173 ± 0.012	51.3 ± 8.1
04262+3544 (3d)	HU 608	459.08 ± 978.17	0.617 ± 0.239	135.5 ± 53.1	188.5 ± 7.3	1888.00 ± 120.62	0.350 ± 0.028	352.4 ± 244.0
04400+2301 (3e)	HU 442	140.23 ± 3.67	0.260 ± 0.017	28.1 ± 9.4	165.6 ± 21.1	1997.53 ± 0.98	0.716 ± 0.017	3.9 ± 24.8
06323+5225 (3f)	WOR 6	53.57 ± 1.41	0.913 ± 0.020	111.4 ± 1.4	110.7 ± 1.4	1980.55 ± 0.13	0.766 ± 0.006	102.6 ± 2.1
06532+3826 (4a)	COU 1877	271.10 ± 61.00	0.793 ± 0.073	58.4 ± 5.4	156.4 ± 7.0	2002.72 ± 6.07	0.487 ± 0.090	59.7 ± 19.9
07303+4959 (4b)	STF 1093	1190.95 ± 529.46	1.320 ± 0.174	41.2 ± 15.9	125.4 ± 12.7	1850.91 ± 42.26	0.470 ± 0.057	336.9 ± 35.9
07560+2342 (4c)	COU 929	44.43 ± 0.32	0.253 ± 0.003	71.5 ± 0.4	187.3 ± 0.3	1953.65 ± 0.29	0.472 ± 0.003	71.5 ± 1.1
09591+5316 (4d)	A 1346	298.13 ± 22.83	0.560 ± 0.045	110.0 ± 1.9	175.9 ± 1.6	1971.51 ± 1.32	0.742 ± 0.020	208.4 ± 2.9
12268−0536 (4e)	A 78	111.93 ± 1.72	0.263 ± 0.005	49.3 ± 2.2	249.9 ± 3.2	1997.50 ± 0.40	0.798 ± 0.008	42.1 ± 4.9
14122+4411 (4f)	STT 278	506.77 ± 15.01	0.518 ± 0.008	149.9 ± 2.1	8.5 ± 6.4	1948.42 ± 1.67	0.434 ± 0.010	355.7 ± 4.5
15031+4439 (5a)	CHR 43	170.88 ± 8.91	0.626 ± 0.047	73.9 ± 2.8	222.2 ± 4.9	1999.39 ± 2.81	0.586 ± 0.028	347.1 ± 13.2
15206+1523 (5b)	HU 1160	177.74 ± 11.99	1.111 ± 0.021	55.2 ± 4.5	39.4 ± 5.2	2004.84 ± 1.20	0.709 ± 0.028	10.1 ± 11.3
15347+2655 (5c)	COU 798	216.23 ± 61.54	0.305 ± 0.072	64.0 ± 4.8	49.7 ± 4.4	1987.11 ± 3.71	0.494 ± 0.122	35.9 ± 11.6
15513−0305 (5d)	CHR 51	44.60 ± 1.20	0.199 ± 0.000	118.0 ± 0.9	90.4 ± 1.8	1994.12 ± 0.21	0.806 ± 0.008	52.9 ± 1.2

Table 3
(Continued.)

WDS (Figure No.)	Discoverer Designation	P (yr)	a ($''$)	i (°)	Ω (°)	T_o (yr)	e	ω (°)
16085−1006 (5e)	BU 949	54.88 ± 0.21	0.363 ± 0.002	84.8 ± 0.6	199.9 ± 0.1	1903.73 ± 0.20	0.847 ± 0.010	131.4 ± 1.5
16216+3631 (5f)	COU 982	88.30 ± 6.94	0.380 ± 0.024	62.1 ± 2.2	74.3 ± 3.1	2000.49 ± 0.56	0.490 ± 0.028	43.5 ± 4.0
17255+0030 (6a)	RST 5432	93.98 ± 4.89	0.285 ± 0.011	141.6 ± 5.6	149.2 ± 9.5	1998.34 ± 1.97	0.274 ± 0.024	228.5 ± 15.3
18018+0118 (6b)	BU 1125 AB	175.74 ± 4.65	1.090 ± 0.027	69.5 ± 3.0	160.2 ± 1.6	2019.87 ± 1.48	0.831 ± 0.035	78.9 ± 4.7
18043+4206 (6c)	COU 1786	56.97 ± 9.62	0.148 ± 0.015	42.3 ± 2.9	202.1 ± 9.0	2045.61 ± 10.85	0.304 ± 0.068	332.8 ± 6.8
20210+4437 (6d)	A 725	166.85 ± 7.08	0.715 ± 0.021	65.7 ± 1.7	226.4 ± 0.9	1959.85 ± 0.97	0.494 ± 0.021	341.4 ± 2.5
20330+4950 (6e)	MCA 61	184.75 ± 33.29	0.133 ± 0.016	46.0 ± 3.8	219.5 ± 4.5	1986.09 ± 0.66	0.612 ± 0.045	266.7 ± 4.8
21047+0332 (6f)	SE 3 BC	654.22 ± 99.48	1.342 ± 0.173	61.2 ± 3.7	162.4 ± 4.1	1971.46 ± 10.02	0.424 ± 0.078	250.2 ± 7.7
21147−0050 (7a)	A 883 AB	81.11 ± 0.78	0.167 ± 0.003	126.8 ± 1.8	116.6 ± 2.8	1946.27 ± 2.14	0.170 ± 0.013	260.9 ± 11.3
22075+2538 (7b)	A 308	174.38 ± 8.71	0.200 ± 0.004	68.4 ± 2.0	305.7 ± 1.5	2015.31 ± 20.58	0.059 ± 0.024	26.1 ± 47.7
22375+2356 (7c)	HU 391 AB	132.11 ± 6.52	0.613 ± 0.030	49.3 ± 14.0	163.2 ± 10.1	2010.44 ± 2.18	0.783 ± 0.079	214.2 ± 16.3
22383+4511 (7d)	CHR 114	35.70 ± 1.56	0.146 ± 0.000	62.8 ± 1.3	83.9 ± 1.5	2013.07 ± 0.78	0.489 ± 0.048	281.4 ± 0.9
23019+4220 (7e)	WRH 37 AB	65.61 ± 4.57	0.250 ± 0.009	107.1 ± 3.0	191.8 ± 2.7	1946.46 ± 6.37	0.523 ± 0.052	32.0 ± 17.5

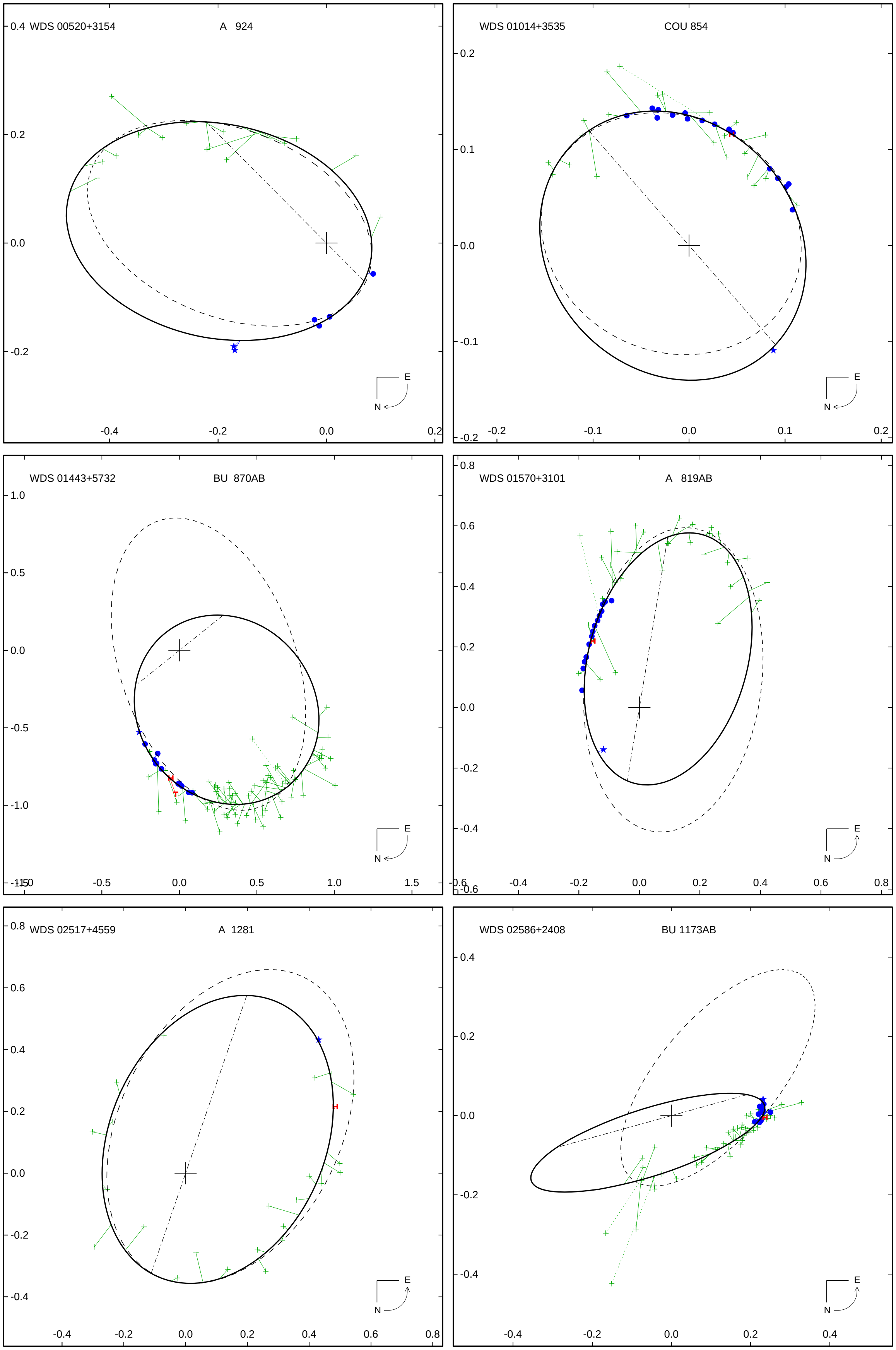

Figure 2. New orbits for the systems listed in Table 3, together with the most recent published elements for these systems and all published data in the WDS database. See the text for a description of symbols used in this and the following figures.

(A color version of this figure is available in the online journal.)

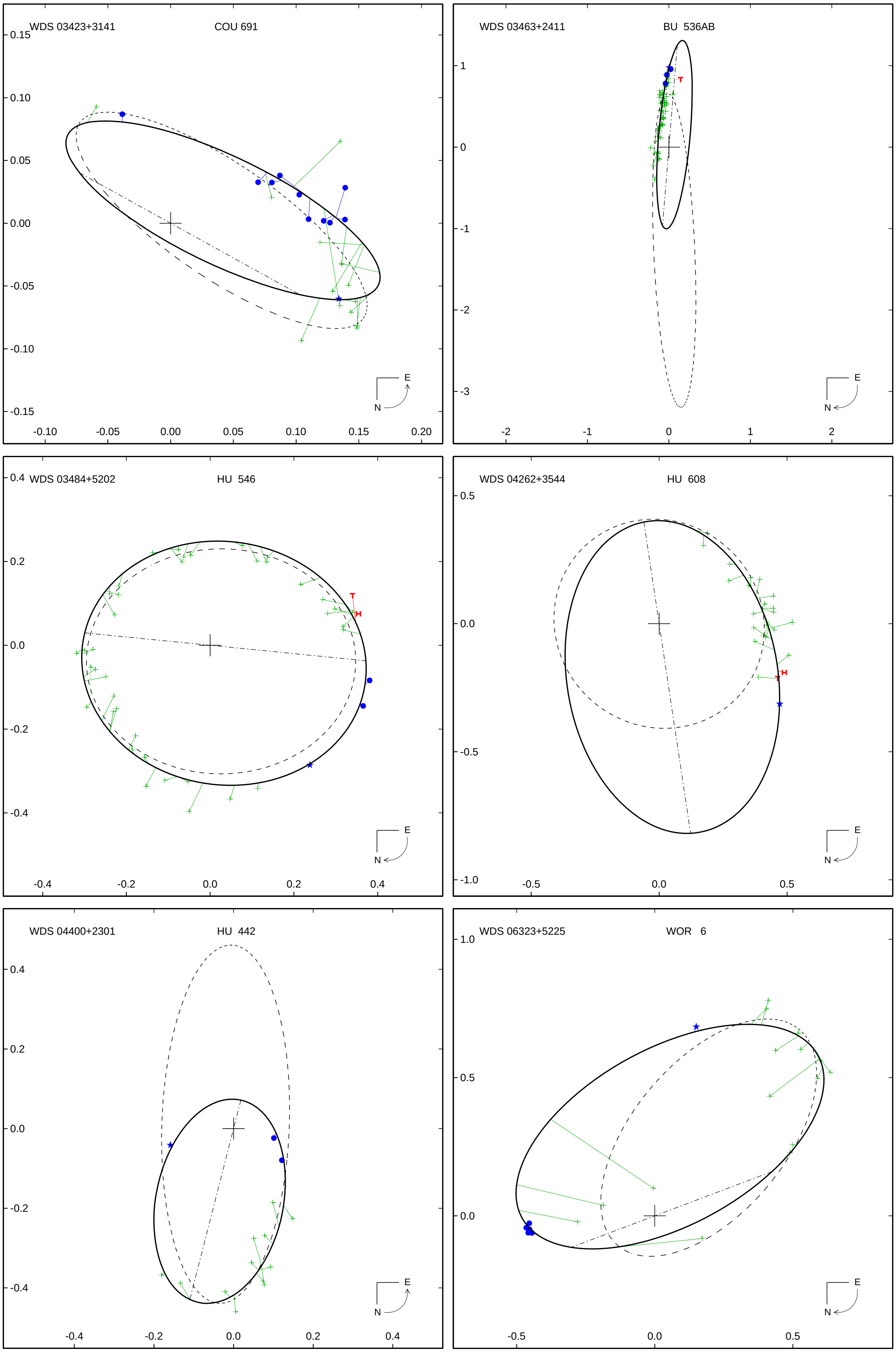

Figure 3. New orbits (continued).
(A color version of this figure is available in the online journal.)

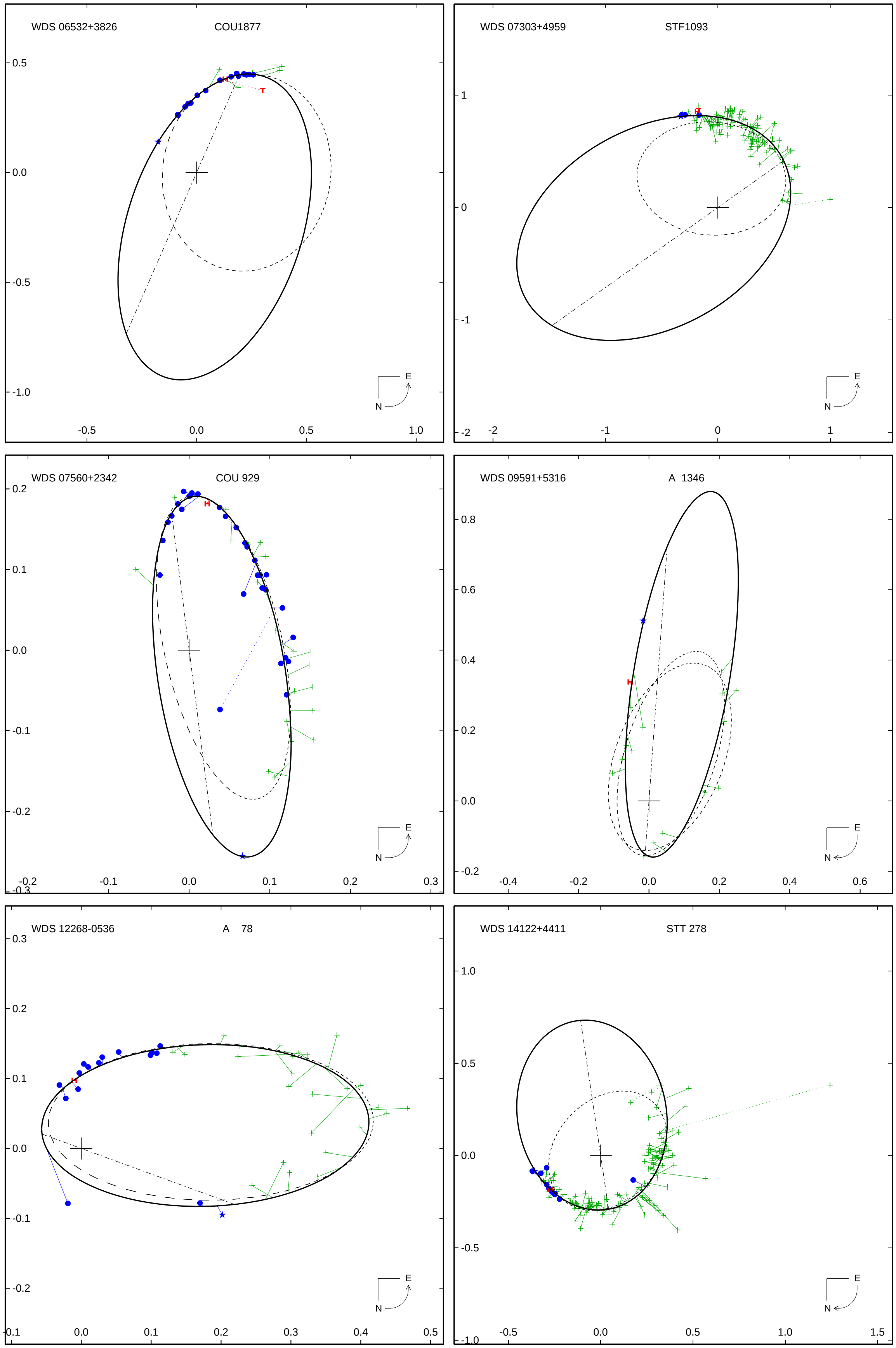

Figure 4. New orbits (continued).

(A color version of this figure is available in the online journal.)

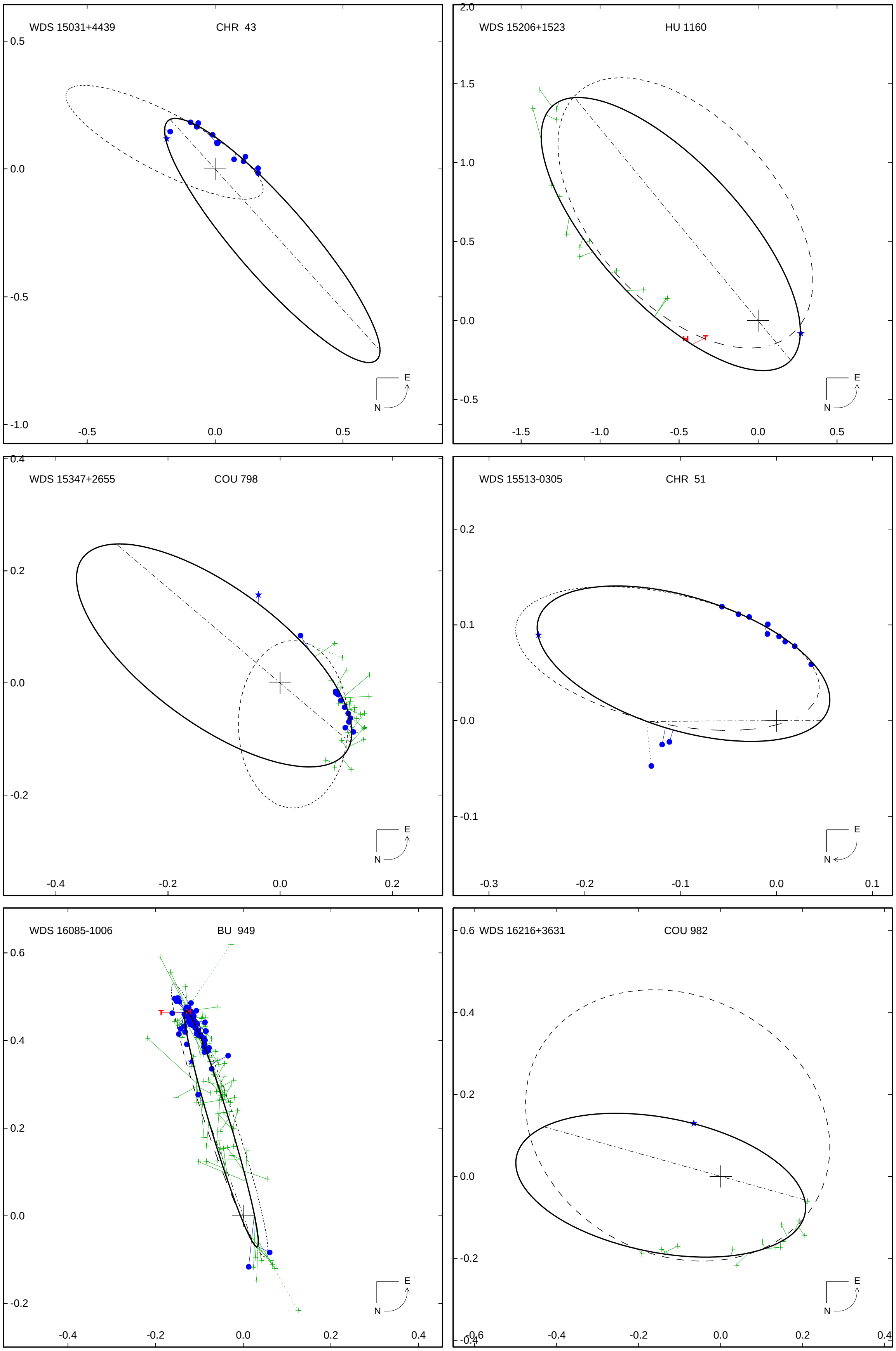

Figure 5. New orbits (continued).

(A color version of this figure is available in the online journal.)

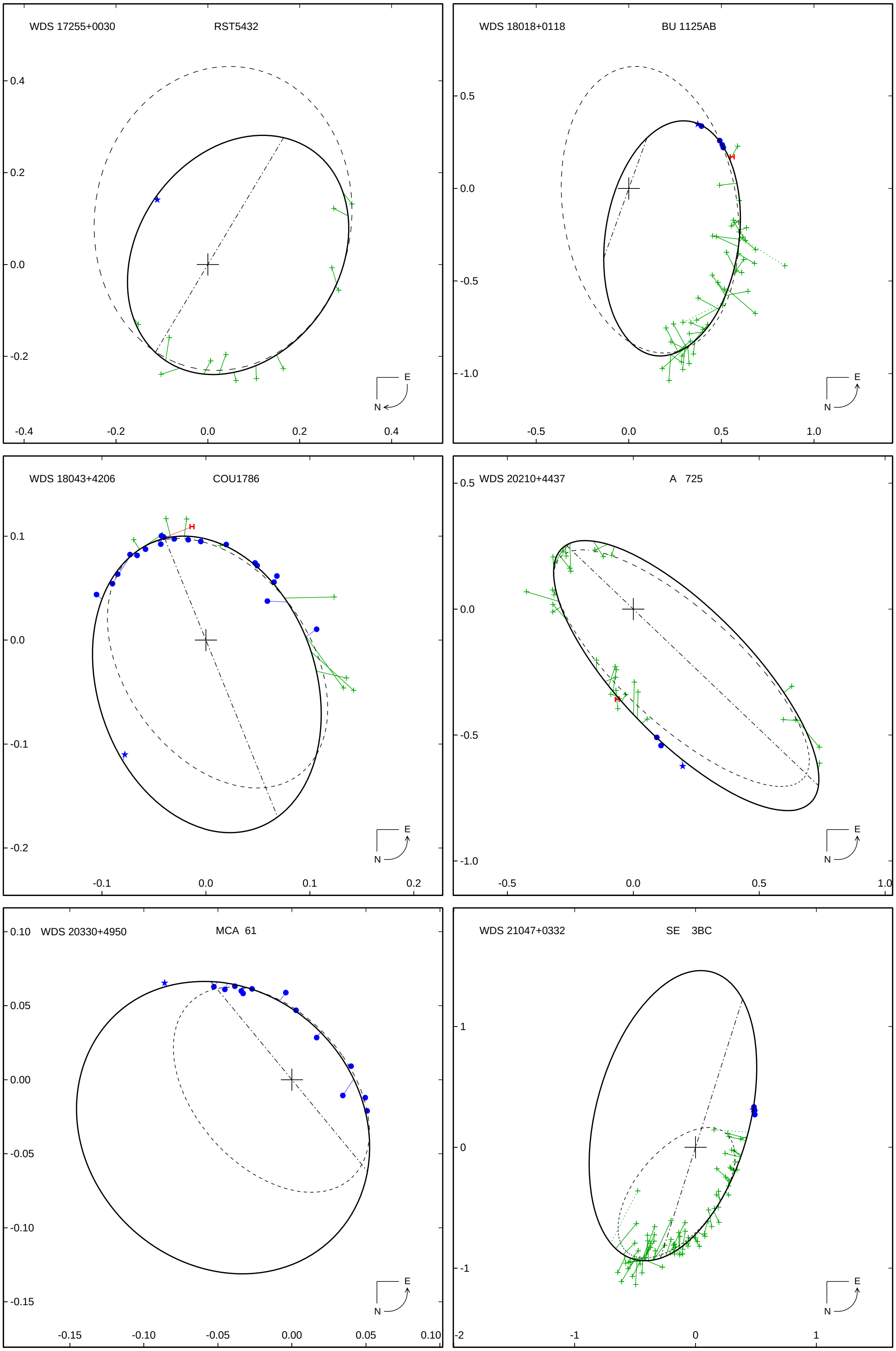

Figure 6. New orbits (continued).
(A color version of this figure is available in the online journal.)

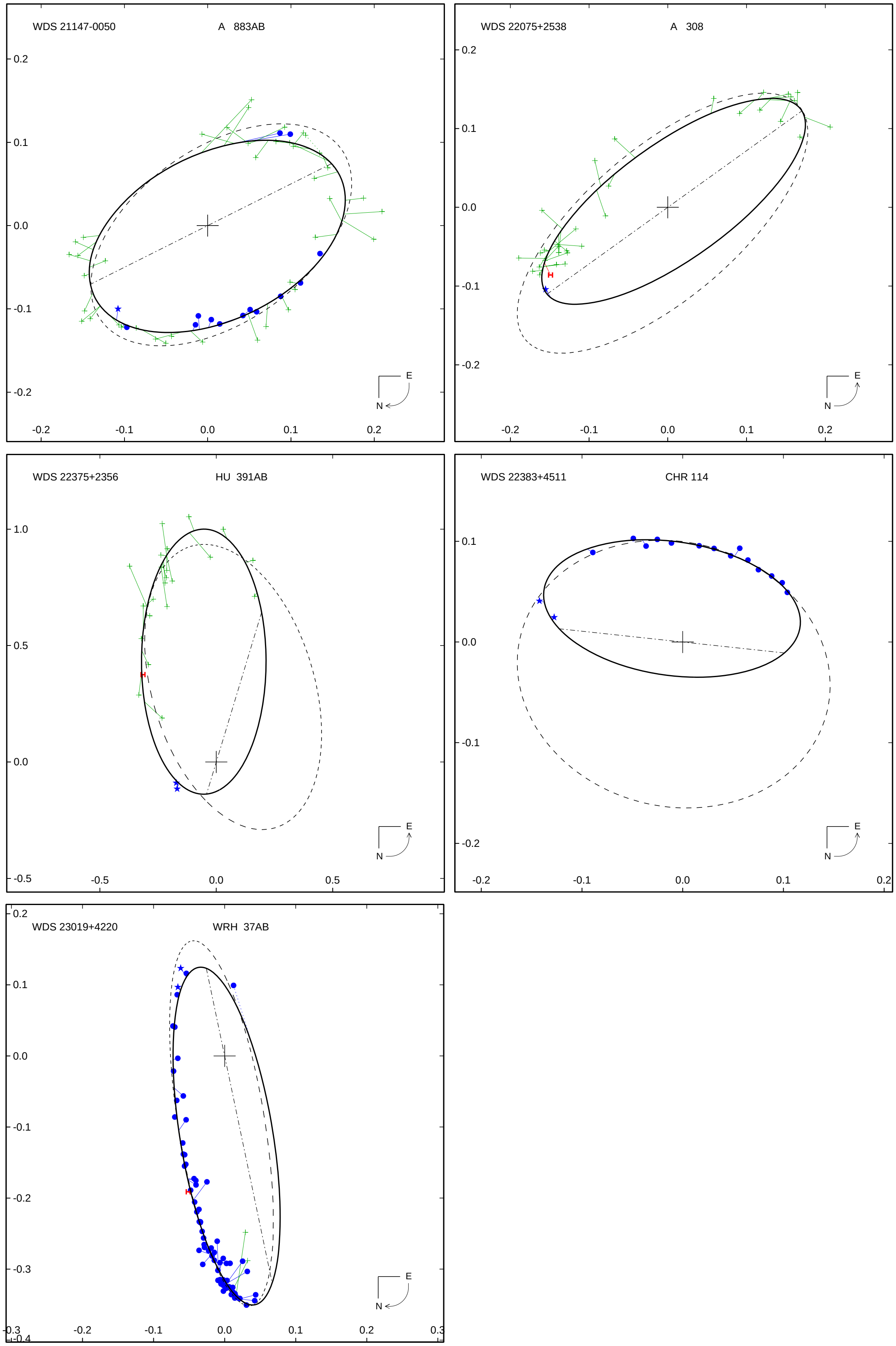

Figure 7. New orbits (continued).

(A color version of this figure is available in the online journal.)

Table 4
Orbital Ephemerides

WDS	Discoverer	2010.0		2012.0		2014.0		2016.0		2018.0		2020.0	
Designation	Designation	$\theta°$	ρ''	$\theta°$	ρ''	$\theta°$	ρ''	$\theta°$	ρ''	$\theta°$	ρ''	$\theta°$	ρ''
00520+3154	A 924	314.5	0.255	311.2	0.268	308.3	0.281	305.6	0.294	303.1	0.305	300.9	0.317
01014+3535	COU 854	28.3	0.139	17.9	0.140	7.6	0.140	357.3	0.140	346.9	0.140	336.5	0.140
01443+5732	BU 870 AB	329.7	0.542	324.7	0.493	318.4	0.438	310.2	0.374	298.2	0.298	277.0	0.212
01570+3101	A 819 AB	329.2	0.217	339.0	0.231	347.7	0.242	355.8	0.251	3.4	0.256	10.8	0.259
02517+4559	A 1281	136.9	0.612	139.1	0.618	141.3	0.623	143.5	0.626	145.6	0.629	147.7	0.630
02586+2408	BU 1173 AB	101.8	0.221	103.2	0.213	104.6	0.204	106.3	0.193	108.1	0.179	110.3	0.162
03423+3141	COU 691	70.7	0.169	74.8	0.173	78.9	0.167	83.5	0.156	89.1	0.140	96.2	0.122
03463+2411	BU 536 AB	179.7	0.982	179.5	0.994	179.4	1.007	179.2	1.019	179.0	1.031	178.8	1.042
03484+5202	HU 546	32.1	0.362	24.1	0.353	15.6	0.345	6.8	0.337	357.5	0.330	347.9	0.324
04262+3544	HU 608	55.3	0.572	54.1	0.580	52.9	0.588	51.8	0.595	50.7	0.603	49.6	0.610
04400+2301	HU 442	293.4	0.183	299.2	0.204	303.8	0.224	307.8	0.242	311.2	0.260	314.1	0.276
06323+5225	WOR 6	161.9	0.718	157.0	0.751	152.6	0.780	148.4	0.805	144.4	0.824	140.6	0.835
06532+3826	COU 1877	247.8	0.224	262.4	0.237	274.9	0.260	285.1	0.290	293.2	0.325	299.7	0.361
07303+4959	STF 1093	201.9	0.874	202.8	0.879	203.7	0.883	204.6	0.887	205.5	0.891	206.4	0.896
07560+2342	COU 929	19.2	0.267	23.4	0.258	28.0	0.241	33.5	0.219	40.3	0.194	49.3	0.167
09591+5316	A 1346	180.9	0.538	180.3	0.558	179.8	0.577	179.3	0.596	178.8	0.614	178.4	0.631
12268−0536	A 78	71.5	0.247	74.1	0.270	76.4	0.290	78.3	0.309	80.0	0.325	81.6	0.339
14122+4411	STT 278	280.5	0.371	278.4	0.376	276.3	0.381	274.3	0.387	272.3	0.392	270.4	0.398
15031+4439	CHR 43	256.2	0.172	271.0	0.146	290.8	0.130	313.0	0.131	332.3	0.148	346.5	0.177
15206+1523	HU 1160	111.3	0.261	137.8	0.299	156.3	0.368	168.5	0.451	176.8	0.537	182.8	0.624
15347+2655	COU 798	201.5	0.170	205.2	0.188	208.2	0.206	210.8	0.222	213.0	0.238	215.0	0.253
15513−0305	CHR 51	246.6	0.270	244.2	0.269	241.7	0.265	239.1	0.257	236.3	0.247	233.2	0.233
16085−1006	BU 949	199.7	0.247	202.3	0.125	21.2	0.072	39.9	0.051	126.3	0.028	172.5	0.072
16216+3631	COU 982	231.0	0.239	237.9	0.290	242.9	0.335	246.7	0.373	249.9	0.406	252.6	0.432
17255+0030	RST 5432	201.5	0.206	191.4	0.224	182.8	0.243	175.4	0.260	168.9	0.277	163.0	0.291
18018+0118	BU 1125 AB	139.0	0.482	143.3	0.453	148.4	0.411	155.0	0.345	166.4	0.232	233.5	0.067
18043+4206	COU 1786	337.4	0.155	344.9	0.165	351.7	0.174	357.9	0.180	3.7	0.185	9.3	0.187
20210+4437	A 725	21.1	0.683	22.7	0.714	24.2	0.743	25.5	0.772	26.8	0.799	28.0	0.825
20330+4950	MCA 61	239.2	0.114	242.0	0.118	244.7	0.121	247.2	0.124	249.6	0.127	251.9	0.129
21047+0332	SE 3 BC	126.1	0.596	128.4	0.622	130.5	0.647	132.5	0.672	134.4	0.698	136.1	0.723
21147−0050	A 883 AB	306.2	0.161	300.6	0.160	294.8	0.156	288.5	0.149	281.6	0.140	273.5	0.128
22075+2538	A 308	310.9	0.183	312.7	0.180	314.6	0.175	316.7	0.169	318.8	0.163	321.2	0.156
22375+2356	HU 391 AB	355.4	0.131	64.2	0.103	115.3	0.171	134.0	0.259	143.3	0.341	149.2	0.414
22383+4511	CHR 114	273.3	0.099	310.7	0.046	56.7	0.059	84.0	0.102	97.9	0.118	110.0	0.118
23019+4220	WRH 37 AB	194.2	0.129	181.9	0.104	153.1	0.057	70.5	0.052	37.5	0.105	27.2	0.159

The pair has completed only a small fraction of its orbit, so any estimate of mass sum is premature.

15206+1523 = HU 1160. At a distance of about 30 pc, NLTT 39960 is the second-nearest pair among the new orbit doubles; it is also the high proper motion pair LHS 5294. It appears to consist of a pair of K2 dwarfs, whose mass sum would fall within the range predicted by this orbit ($1.2 \pm 0.5\ M_{\odot}$).

15513−0305 = CHR 51. No magnitude difference has been published for this pair, but judging by the separation, observer's notes, and the known magnitude limit of the speckle technique, it may be estimated at perhaps 1 mag at most. The primary is of spectral type A3Vn; the secondary is probably mid- to late-A, and the predicted mass sum ($0.5 \pm 0.1\ M_{\odot}$) is obviously an underestimate.

16085−1006 = BU 949. The orbit is both highly inclined and eccentric. Spectral types are F7V and roughly G5; the predicted mass sum ($2.4 \pm 0.6\ M_{\odot}$) is reasonably plausible.

18018+0118 = BU 1125 AB. Also known as 68 Oph, one component of this pair is a variable star and possibly a spectroscopic binary. Phase coverage is still too incomplete for mass determination.

18043+4206 = COU 1786. Elemental errors are rather high, so the derived mass sum has a fairly large uncertainty ($3.5 \pm 1.4\ M_{\odot}$). The spectral types are F0 and perhaps F5, with an expected mass sum of about 3 $M_{\odot}$.

20210+4437 = A 725. Spectral types are K0 and perhaps K2 or a little later, in good agreement with the calculated mass sum of $1.5 \pm 0.5\ M_{\odot}$.

20330+4950 = MCA 61. This pair was discovered by a photographic speckle technique in 1980 (McAlister et al. 1983) and has remained a close pair, although it is beginning to widen. Relative errors to both period and parallax are too large for mass determination.

21047+0332 = SE 3 BC. The secondary of the ∼3″ visual pair STF 2749 (Struve 1837) was found to be double when Secchi (1860) split the B component in 1856. Lewis (1895) also split the A component in 1895, but this pair has been unseen except for three instances in the 1890s; these observations may actually have been of the Secchi pair instead. A wider D component was measured in 1920, but remains unconfirmed.

21147−0050 = A 883 AB. Star C (mag. 10.37, 21″ separation) is thought to be probably physical, but the physical/optical nature of five other wide companions is unknown. The primary is of spectral type A1V, the secondary about A5; if it is indeed a physical companion, the C component would perhaps be of about F5 spectral type, based on the magnitude difference.

22075+2538 = A 308. Spectral types are about A2 and A5, yielding an estimated mass sum of 4.5 $M_{\odot}$. This orbit predicts a mass sum of 4.9 $M_{\odot}$—good agreement, albeit with an uncertainty of $\pm$ 4.1 $M_{\odot}$!

22375+2356 = HU 391 AB. The A and B components are of spectral types K8 and ∼M0. A third component ($V = 12.4$, separation $\approx 6''$) shares a similar proper motion and is probably physical; its type is probably M2–M5.

22383+4511 = CHR 114. A G2III + A4V, but the predicted mass sum is in complete disagreement with these spectral types. The orbit is still uncertain, however, and the close separation could also have led to difficulties in deriving a good parallax.

23019+4220 = WRH 37 AB. Omicron And. The AB pair was first "officially" resolved by eyepiece interferometry in 1949 (Wilson 1950). However, that measure is so discrepant compared with other observations that the first actual resolution of this pair was probably that of McAlister & Hendry (1982), using a speckle camera at the KPNO 2.1 m in 1976. The primary is an 8y period, 40 mas pair discovered by speckle interferometry in 1975 (Blazit et al. 1977). SIMBAD also describes it as a β Lyr-type eclipsing binary. Finally, the B component is an SB2, with 33.01d period (Olević & Cvetković 2006).

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